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Development of PV array configuration under different partial shading condition

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ABSTRACT

This paper investigates the performances of different photovoltaic (PV) array under several shading condition. Four types of photovoltaic array configuration scheme which are 'Series' (S), Series-Parallel' (SP), Total-Cross-Tied' (TCT), and 'Bridge-Link' (BL) array topologies were tested by applying a 6x6 PV array under 6 different shading scenarios. The modeling is developed using Matlab/Simulink. The performances and output characteristics of photovoltaic array are compared and analyzed. System engineer can use the detailed characteristics of different array configuration to approximate the outcome power and pick the best configuration of the system by concerning the current natural condition to enhance the overall efficiency.

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1. INTRODUCTION

Growing interest of renewable energy sources and solar photovoltaic (PV) has become more significant to generate clean energy[1-4]. However it have some disadvantages which are low energy conversion performance, high initial cost of purchasing the solar system itself, and dependence of power output on weather or atmospheric condition [5-7]. The outputs of PV devices are non-linear due to its dependency to the environmental conditions such as solar irradiance and temperature [8].

There are numerous elements that make contributions to the reduction of output electricity from PV arrays. One of the main reasons that contribute the loss of output power is partial shading [9]. In large PV installation, the partial shading will reduce the efficiency of the overall system. It is impractical to keep away from the partial shading of the array in all weather conditions and seasons [10]. The output of PV module always depends on the solar irradiance and temperature. The solar energy can be change to electrical energy by using PV cell, module or array.

Several researchers have studied the consequences and explored the remedies of partial shading on PV systems. One of the best solutions in this direction is PV array configuration. Different PV array configurations that have been proposed in the literature are: Series (S), Parallel (P), Series-Parallel (SP), Total-Cross-Tied (TCT), Bridge-Linked (BL) and Honey-Comb (HC). In [11-13], a MATLAB-based modeling and simulation scheme suitable for studying the performance of the maximum output power generated.

In a normal condition, power – voltage (P-V) and current – voltage (I-V) curve will only have one peak value, whereas under partial shading condition (PSC) the curve will be multiple peaks. Therefore, the designer has to choose the right or suitable value and use the maximum power point tracking (MPPT) to track the maximum power [14-15]. MPPT is largely a dc-dc converter which makes use of an

algorithm to determine the maximum power point (MPP) of the P-V and I-V characteristics in varying environmental situation [16-17].

In [18], generalized MATLAB M-code has been developed to suit with any required array size, configuration, shading patterns and number of bypass diodes. Modeling and comparison of the performance of different PV array configurations under various PSCs is presented [19]. The performance of existing and some proposed solar PV array configurations is investigated comprehensively in [20]. In [21], a full investigation of only Total-Cross-Tied (TCT) configuration under PSC is done neglecting other configurations. Interconnections whose performance lies in between SP and TCT interconnections are proposed in [22] to create a clear correlation between number and location of shaded modules, interconnections and maximum power obtained

In [23], reconfiguration of array has been made by way of converting connection of all modules on the array. The proposed circuit which is a combination of a buck–boost converter and the switched-capacitor (BBSC) circuits, equalizes the voltage of PV modules and prevents bypass diodes from bypassing the shaded modules in a string [24]. The author in [25] is proposed by using Binary Search Algorithm (BSA) to determine the maximum power point (MPP) in photovoltaic (PV) system under partial shaded conditions.

In this paper, 6 different shading case studies on 6 by 6 PV array, the performance of Series (S), Series-Parallel (SP), Total-Cross-Tied (TCT), and Bridge-Link (BL) configurations were analyzed. Matlab/Simulink is used as a simulation tools to construct all PV array configurations under different shading cases. The comparisons of the performances of photovoltaic array configuration in terms of output power were made.

2. RESEARCH METHOD

2.1. Structured of the photovoltaic array

Analysis and comparisons of the output characteristic of PV array with S, SP, TCT and BL configurations were made in this study. The array consists of 36 photovoltaic modules in a 6 x 6 array arrangement and a PV module simulation model. Figure 1 shows the block diagrams of the photovoltaic module simulation model. The maximum power point, P_{max}, open-circuit voltage,V_{OC}, short-circuit current I_{SC}, voltage at the maximum point, V_{mp} and current at the maximum point, I_{mp}. All of the parameters mentioned above are given under Standard Test Conditions (STC) in the manufacturer's datasheet.

The variant is justified by applying parameters of SunPower SPR-X20-250-BLK solar panel from datasheet. Parameters of solar PV module are shown in Table I.

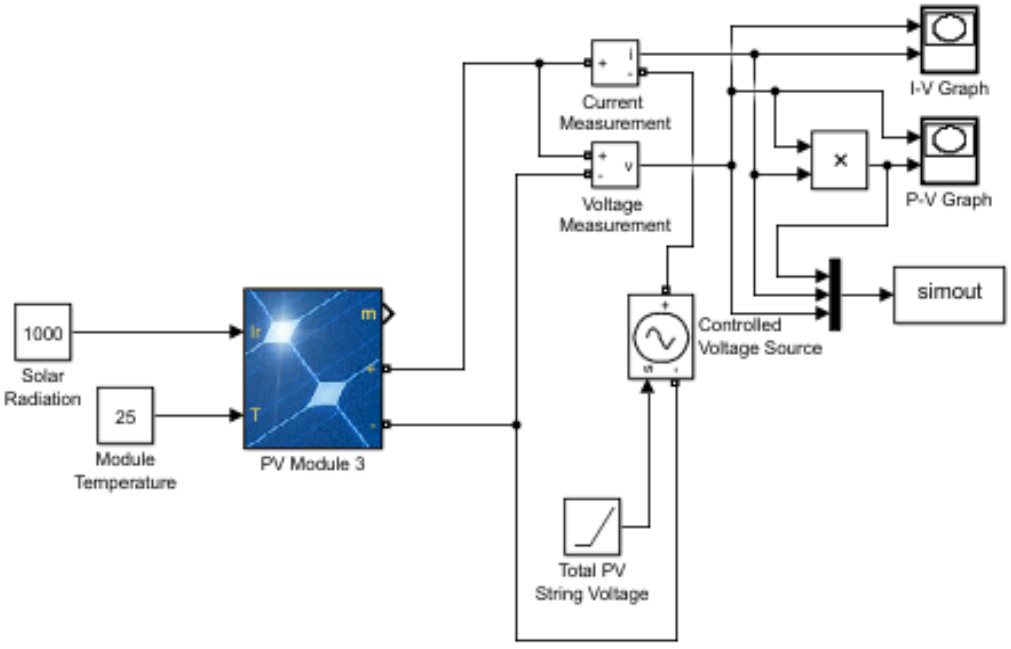

Figure 1. PV Module simulation model in Matlab/Simulink

Table 1. The PV Module parameter

Variables	Parameter	Value
Pmax	Maximum power	250 W
Impp	Maximum power point current	5.84 A
Vmpp	Maximum power point voltage	42.8 V
Isc	Short circuit current	50.9 V
Voc	Open circuit voltage	50.9 V
Kp	Temperature coefficient of Pmpp	-0.30% / °C
Kv	Temperature coefficient of Voc	-125.6 mV / °C
Ki	Temperature coefficient of Isc	3.5 mA / °C
Ns	Number of series cell	72

2.2. I-V and P-V characteristics of photovoltaic array under identical illumination

The efficiency and maximum output power of PV module can be affected by the changing of solar irradiance value and temperature. The temperature that received by the solar panel is inversely proportional to the generated output power. For solar irradiance, it has almost linear effect on current and power and marginal effect on voltage. The Current-Voltage (I-V) and Power-Voltage (P-V) characteristics of PV module running at same temperature of 25°C and different of irradiance value are given in Figure 2 and Figure 3.

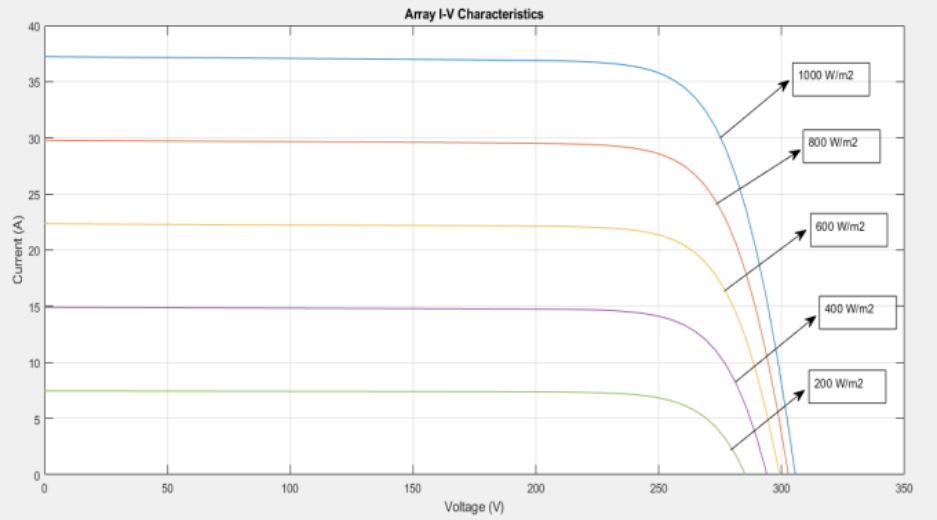

Figure 2. I-V Characteristics of simulated array with different irradiance value

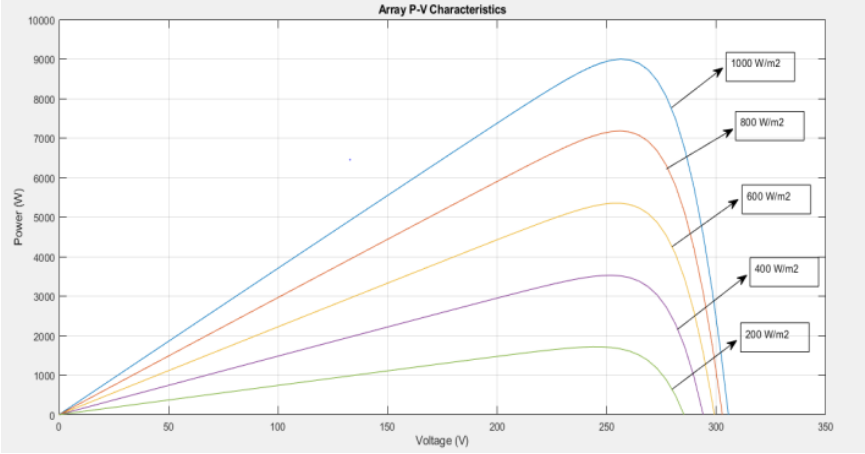

Figure 3. P-V Characteristics of simulated array with different irradiance value

2.3. PV array configuration

PV Module is developed by joining several PV cell into one unit. Normally, a PV module consists of 36 cells that connected in series configuration, however other connection are also feasible. Figure 4 shows the connection of the PV Module in Series, Series-Parallel, Total-cross-tied and Bridge-link with 36 PV cells used in the simulation.

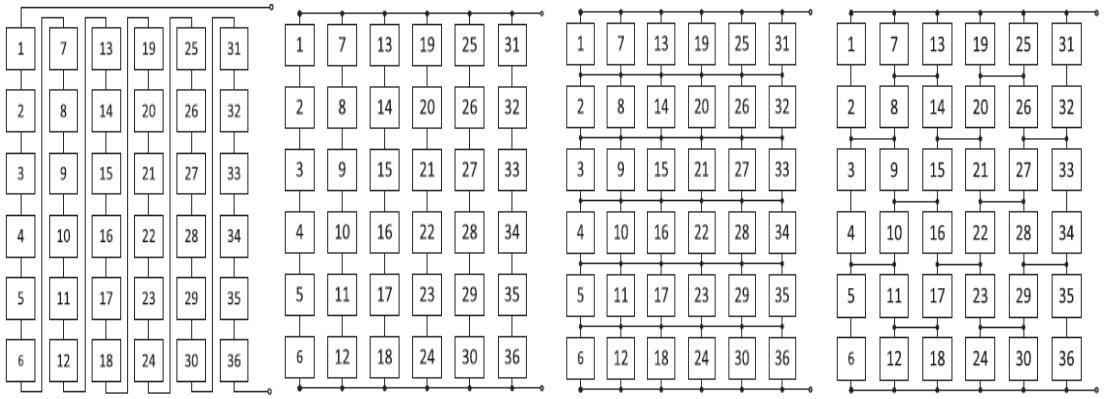

Figure 4. Schematic diagram of 36 PV arrays (6 x 6) in different configuration

2.4. Modelling of partial shading effects

This study focused to investigate and identify the performances of dissimilarity of array configuration under several shading condition or scenario. There are 6 different shading patterns which they are represented as the passage of a cloud over the PV array. There are 3 different irradiance value in each pattern which are 1000 W/m2, 500 W/m2, and 200 W/m2 to represent the fully illumination condition, half clear cloud and most dimness of cloud focus. The shading scenario can be described according to:

- First Shading Scenario: The value of solar irradiance that set for 4 modules that located at left bottom of the array are 200 W/m2 while 12 modules that irradiated with 500 W/m2 and remaining 20 modules fully received light with 1000 W/m2.
- Second Shading Scenario: The value of solar irradiance that set for two row at the bottom of the array are 200 W/m2. This has covered 12 modules while two rows at the middle of the array are partly shaded with 500 W/m2 and remaining two rows at the top of the array are fully irradiated with 1000 W/m2.
- Third Shading Scenario: The value of solar irradiance that set for two columns at the right side of the array is 200 W/m2. This has covered 12 modules while two columns at the middle of the array are partly shaded with 500 W/m2 and remaining two columns at the left side of the array are fully irradiated with 1000 W/m2.
- Fourth Shading Scenario: The value of solar irradiance that set for two rows at the top of the array are 200 W/m2. This has covered 12 modules while two rows at the middle of the array are partly shaded with 500 W/m2 and remaining two rows at the bottom of the array are fully irradiated with 1000 W/m2.
- Fifth Shading Scenario: The value of solar irradiance that set for 4 modules at the middle of the array are 200 W/m2 while 12 modules are partly shaded with 500 W/m2 and remaining 20 modules received light with 1000 W/m2.
- Sixth Shading Scenario: The value of solar irradiance that set for 4 modules at the middle of the array are 1000 W/m2 while 12 modules are partly shaded with 500 W/m2 and remaining 20 modules received light with 200 W/m2.

3. RESULTS AND ANALYSIS

The simulation are executed by using Matlab/Simulink software. All the configurations namely Series, Series-Parallel, Total-Cross-Tied, and Bridge-Link are compared in term of their disapearance output power under partial shading condition (PSC). The comparison is analyzed by based on the different irradiance value and shading scenario. Figure 5 shows Power-Voltage characteristics of the mentioned array configuration under 6 partial shading scenarios.

Based on Table 2, the maximum output power in the case shading scenario 1, 5, and 6 for TCT is higher compared with the other three of PV array configuration. Meanwhile, based on Table IV, V and VI show the maximum output power in the case shading 2, 3, and 4 for TCT, BL and SP produced the same maximum output power if compared with S configuration that produced least output power.

Table 2. Maximum output power for shading scenario 1-6

Configuration	Scenario 1		Senario 4	
	Pmax (W)	Number of peaks	Pmax (W)	Number of peaks
Series	480,531,330	3	2355,2038,330	3
Series-Parallel	2957,4407,5193	3	2877,3183,1983	3
Total-Cross-Tied	2878,4202,5470	3	2877,3183,1983	3
Bridge-Link	2900,4302,5310	3	2877,3183,1983	3
Configuration	Scenario 2		Scenario 5	
	Pmax (W)	Number of peaks	Pmax (W)	Number of peaks
Series	480,530,330	3	1500	1
Series-Parallel	2877,3183,1983	3	2957,4407,5193	3
Total-Cross-Tied	2877,3183,1983	3	2878,4202,5470	3
Bridge-Link	2877,3183,1983	3	2878,4267,5382	3
Configuration	Scenario 3		Scenario 6	
	Pmax (W)	Number of peaks	Pmax (W)	Number of peaks
Series	1500	1	1155,1343,286	3
Series-Parallel	5036	1	1685,2441,1817	3
Total-Cross-Tied	5036	1	1610,2477,1946	3
Bridge-Link	5036	1	1635,2436,1937	3

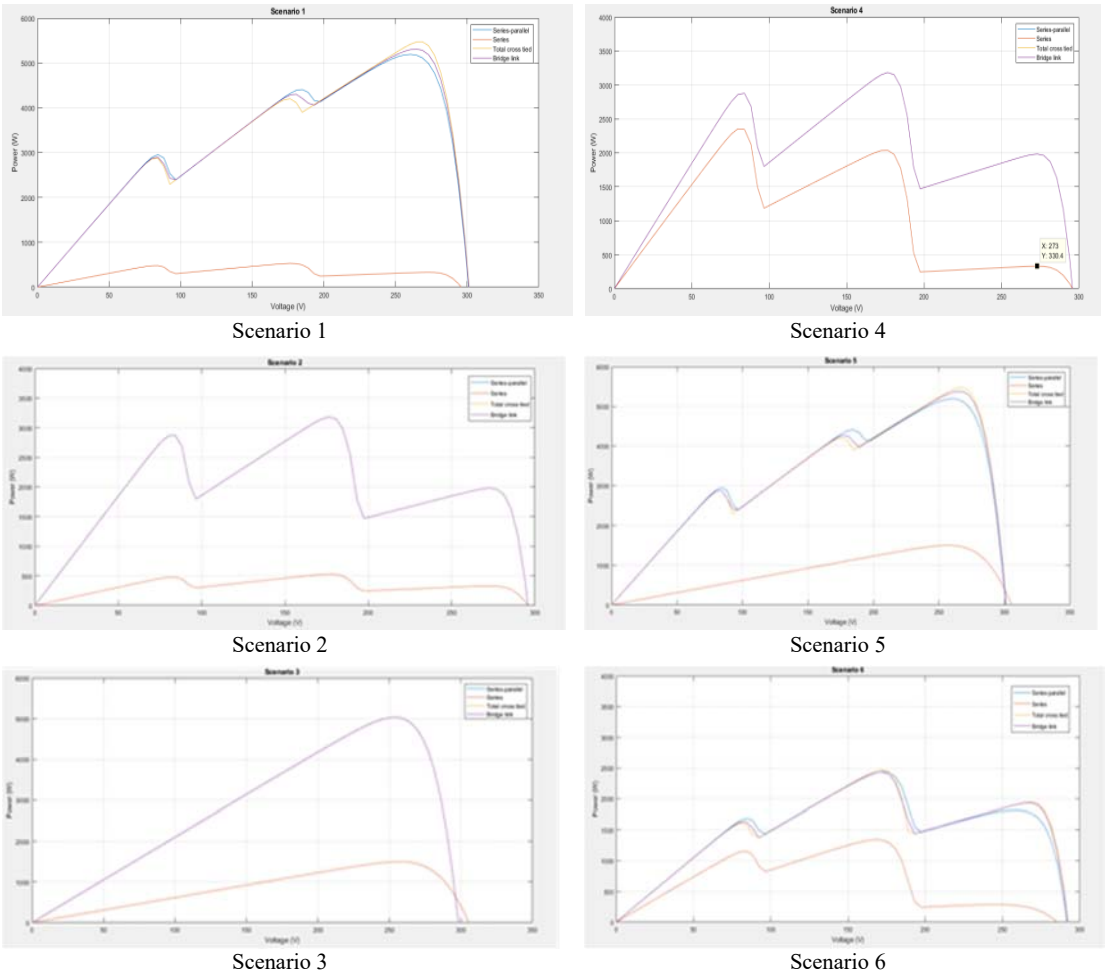

Figure 5. P-V characteristics of 4 different photovoltaic array configurations in 6 different scenario

From the result, it shows the Total-Cross-Tied setting has shown the greatest performance in every partial shading scenario and it can be considered that even though its pattern is complex, it is beneficial with the presence of extra-complicated shading scenario in actual surroundings or practical state.

4. CONCLUSION

In the study, a simulation technique is used for analyzing PV modules with four different of photovoltaic array configuration which are Series, Series-Parallel, Total-Cross-Tied and Bridge-Link configurations respectively by using Matlab/Simulink software. The assessment of four connection configurations has been done through using 36 PV modules and evaluating in terms of their maximum output power for four configuration schemes. The effect of partial shading to the PV modules on the Series, Series-Parallel, Total-Cross-Tied and Bridge-Link configurations also have been investigated under 6 different shading scenarios. Referring to these results, Total-Cross-Tied configuration the highest maximum output power even though under partial shading conditions compared to other configurations. As a result, PV array configuration strongly affecting the efficiency of PV array. The result that offer or provide is very beneficial and trustworthy details on the performances of array configuration in different shading situation or scenario. All the information can be used to enhance whole efficiency of the photovoltaic system during design the system.

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